Verification of Commands From the Transmitting Medium

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A system for bit-by-bit verification of Pioneer command modulation by sampling the S-band transmitted signal directly at the antenna is described. This system was installed at DSS 14 and operated flawlessly during the entire 60-day Pioneer 10 encounter sequence.

I. Introduction

The very long round trip light times and the lack of on board command storage associated with the Pioneer project necessitate an extremely high confidence in the accuracy of commands transmitted to the spacecraft. Ideally, one would like to monitor directly the signal sent to the spacecraft to ensure that no anomalies in command transmission have occurred. In September 1973, the concern for command verification increased in light of the extremely high command activity anticipated for Pioneer 10 encounter (approximately 400 per day). In response to this concern, a system was devised and implemented at DSS 14 that monitored the S-band transmitted energy at the station antenna, detected uplink command modulation, and compared the detected command sequence bit by bit with a replica from the Command Modulator Assembly (CMA). The only ground rules for the system were that it could not interfere in any way with the operating system and that it must be capable of installation within two months. The scheme was named Command Medium Verification, since it verified commands directly at the transmitting medium.

II. Description of the System

A block diagram of the system is shown in Fig. 1. The S-band transmitted energy is monitored by using the old zero delay antenna. This antenna consists simply of a WR430 waveguide to coaxial adapter mounted in the antenna dish and coupled to the control room through a hardline coaxial cable. Once in the control room, the S-band signal was demodulated by using the Deep Space Instrumentation Facility (DSIF) test transponder.

The DSIF test transponder contains a crystal voltage-controlled oscillator (VCO) and is similar in structure to the Block III C S-band receivers. However, the tracking range of the transponder was significantly less than the doppler profile for the Pioneer spacecraft. To broaden the tracking range, the VCO section was disabled and replaced by a more elaborate VCO consisting of a Fluke 533A synthesizer and a frequency doubler. The Fluke synthesizer was selected since it has a remote search capability that is symmetrical around the selected center frequency. The transmitter section of the transponder was not required and was consequently disabled.

The baseband output of the transponder receiver containing the Pioneer frequency-shift keyed (FSK) command modulation was applied to the Command Medium Verification control unit (shown in Fig. 2) along with the tone output of the appropriate CMA. The purpose of the control unit was to provide bit detection and comparison as well as to provide an interface with an oscillograph recorder. The recorder provided a permanent visual record of the command activity.

The transponder baseband and CMA output were applied to filter amplifiers for amplitude separation of the tones on the recorder. In addition, the signals were applied to phase locked tone decoders that demodulated each tone stream to a command bit sequence. Each bit sequence was then applied to a three-level amplifier for recording on the oscillograph. The three-level amplifier provided one level for a data "1", a second level for a data "0", and a level midway between the others when neither tone frequency was present.

To provide bit error detection, a bit centered clock stream was generated. This was accomplished by utilizing the 100-pulse-per-second (100 pps) signal from the frequency and timing subsystem (FTS) to drive a symmetrical divide by 100 circuit. The divider was inhibited until the time when command modulation was detected. From this point on, the divider would produce a 1-Hz squarewave with a negative going transition at the center of each command bit. This transition was used to sample each decoded bit stream and, if the samples of the two streams differed, generate an error pulse. The error pulse was recorded on the oscillograph and also was used to turn on an error indicator lamp. To establish the time at which commands and/or errors occurred, a 28-bit digital NASA time code available in the FTS was amplified and recorded on the oscillograph.

The oscillograph recorder used for the system was a Honeywell Model 1508 "Visicorder." This oscillograph uses light reflecting galvanometers to record on photosensitive paper. A sample recording of a 22-bit Pioneer command is shown in Fig. 3.

III. System Performance

The command verification system was installed at DSS 14 in time for the Pioneer 10 encounter sequence. Upon implementation, the system was exercised to determine its operational capabilities. It was found that the modified test transponder could track doppler offset frequencies in excess of 100 kHz (at S-band) on either side of the selected frequency, and that it could follow S-band frequency ramps in excess of 200 Hz/s. Furthermore, the command demodulation and comparison capability was found to be unaffected by these stress conditions until the time at which the transponder receiver broke lock. After initial testing, the system was used without incident by operations personnel during the entire Pioneer encounter period.

IV. Conclusions

The system described in this article represents a satisfactory method for the bit-by-bit verification of the uplink Pioneer command modulation directly at the antenna. Furthermore, the modified receiver scheme presented herein may prove useful in the future for monitoring almost any type of uplink modulation.

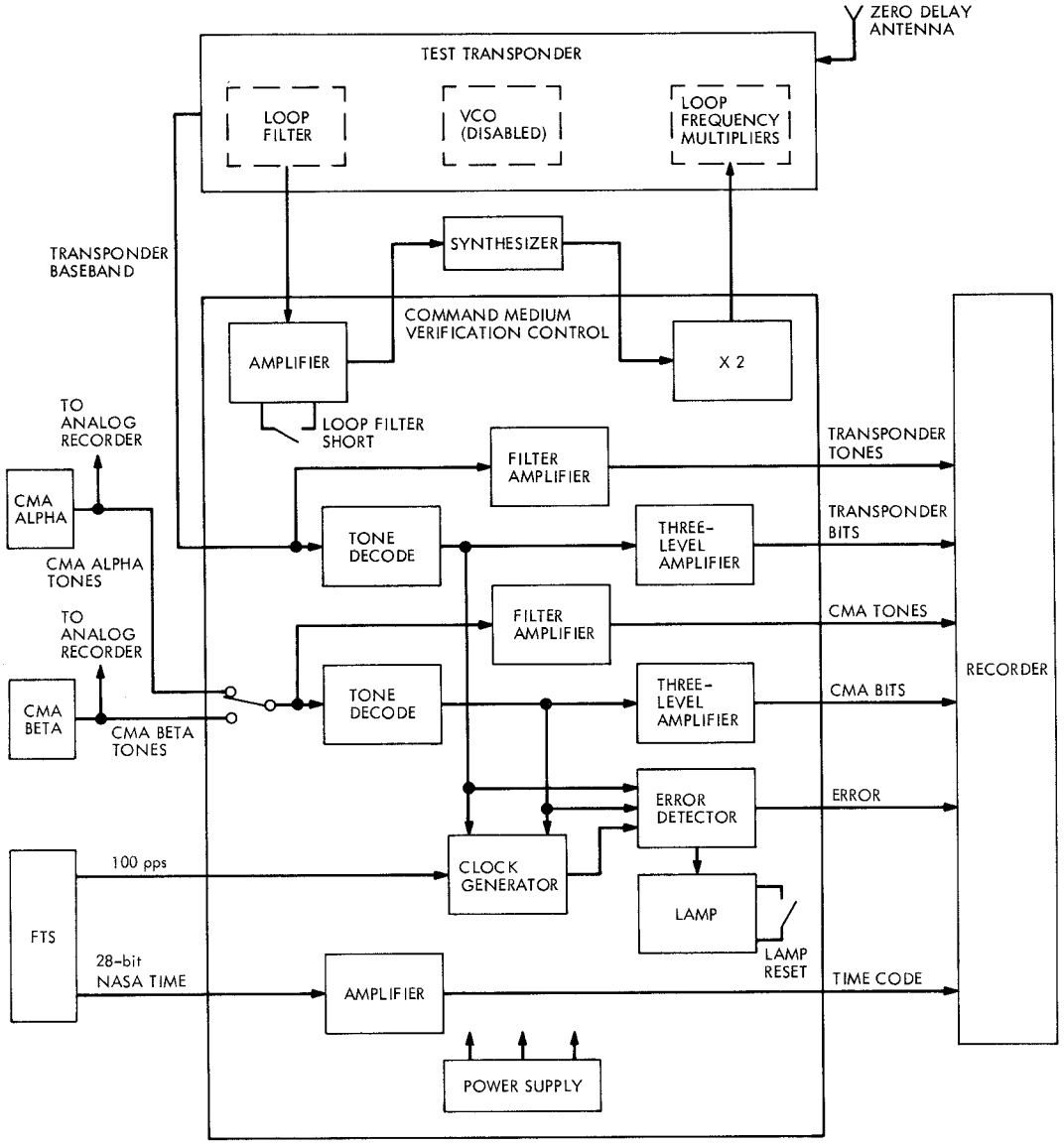

Fig. 1. Function block diagram, Command Medium Verification System

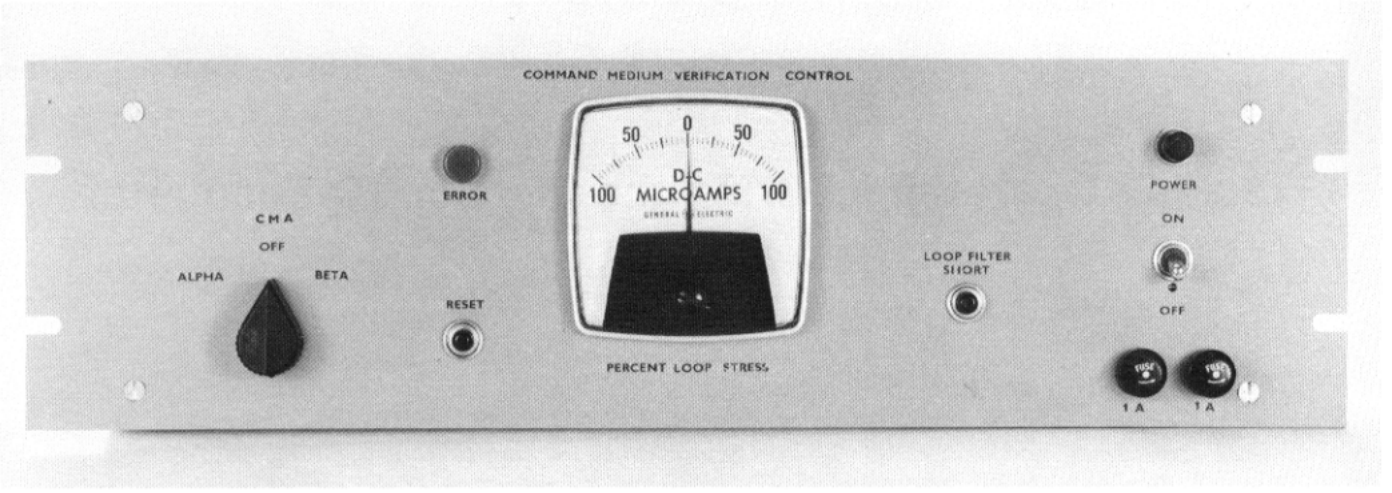

Fig. 2. Front panel, Command Medium Verification control unit

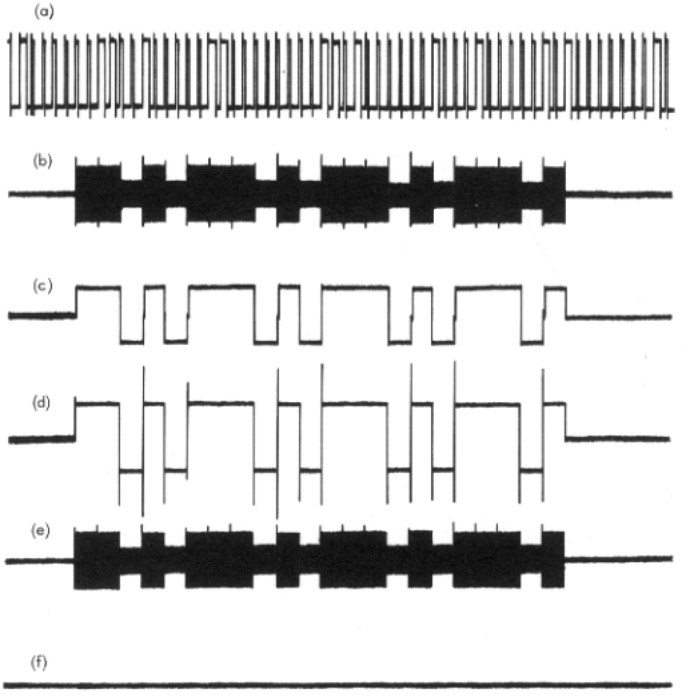

Fig. 3. Typical oscillograph recording of a Pioneer command. Individual traces are: (a) NASA time code; (b) CMA tones; (c) CMA bits; (d) transponder bits; (e) transponder tones; and (f) bit error line (no bit errors present on this recording)